Putting forests to work? Enrolling vegetal labor in the socioecological fix of bioenergy resource-making

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Abstract

Large-scale European electricity providers are increasingly replacing coal with renewable biomass wood pellets produced from working forests of the U.S. South. Adopting a posthumanist interpretation of the labor theory of value, this paper argues that wood pellet manufacturing constitutes an attempt by energy capital to substitute the 'dead labor' of prehistoric plants, embodied in fossil fuels, with the living, 'vegetal labor' of forests of the present-day. More specifically, the paper contends that by capitalizing on the 'hybrid labor' regimes through which the real subsumption of nature in working forests is achieved, energy interests seek to position wood pellets not merely as a viable alternative resource for electricity generation, but as a socioecological fix for capitalist crisis linked to climate change in the European energy sector. The legitimacy of this apparent fix depends, however, on normalizing a view of forests not as gradually accumulating carbon sinks, but as high-throughput carbon conveyors. Wood pellet manufacturing thus has important implications for conceptual understandings of the role played by labor—both human and vegetal—in efforts to institute socioecological fixes, and also for practical efforts to challenge the inherently productivist logics of expanding forest-based bioenergy systems, whether rooted in the U.S. South or elsewhere.

Key Words: bioenergy, real subsumption of nature, socioecological fix, vegetal labor, working forests

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Introduction

Amid growing concern about anthropogenic climate change, wood pellets produced from the forests of the southern United States are increasingly being used to replace coal with bioenergy in the European Union (EU) electricity sector. Driven by policies incentivizing the conversion of EU coal-fired power facilities to run on biomass (Abt et al. 2014), wood pellet production in the U.S. has expanded rapidly in the past decade. Production capacity is estimated to exceed 13 million tons, of which approximately three quarters is concentrated in the U.S. South region (Oswalt et al. 2019, 47). Over six million tons of wood pellets were exported from the U.S. to the EU in 2018 (USDA Foreign Agricultural Service 2019), of which approximately 80% were burned at large-scale power facilities in the United Kingdom (UK) (European Commission 2019). Biomass fuels in fact generated 28% of UK renewable electricity in the first quarter of 2019, roughly equal to the amount generated by offshore wind farms (BEIS 2019). Elsewhere in the EU, meanwhile, dozens of additional 'coal-to-biomass' conversions are planned at major power facilities in countries including Finland, Germany, Ireland, Spain and the Netherlands (Sandbag 2019).

Wood pellet manufacturing is highly contentious. Some analyses have concluded that electricity generated by this new fuel source may, depending on processing and transportation emissions, as well as the length of time required to subsequently regrow trees, end up being more harmful to the global climate than continuing to burn coal (UK DECC 2014; Matthews et al. 2015). Others have raised concerns about the potential impacts of wood pellet production upon forest biodiversity, particularly in ecologically-sensitive parts of the U.S. South (Schlesinger 2018). Though efforts to determine the precise environmental impacts of wood pellet manufacturing are important, this paper does not concern itself with this question. Instead, it uses the case of wood pellet manufacturing to examine the theoretical and political implications of reorienting energy systems in the global North away from fossil fuels—essentially dead organic matter—and towards living biological resources (in this case trees).

At one level, wood pellet production in the U.S. South represents the latest addition to a well-established family of forest-product industries whose profitability derives from the "real subsumption of nature" (Boyd, Prudham, and Schurmann 2001). Indeed, much of the region's forest has for decades been referred to as 'working forest'—denoting its status as a landscape managed expressly to produce wood-based commodities—having long played host to efforts to "directly augment natural processes and use them as strategies for increasing productivity" (*ibid.* 2001, 557). Wood pellet manufacturing, however, differs from pre-existing forest-product industries in that its legitimacy derives principally from its contribution to climate change mitigation, and hence from its ability to achieve the real subsumption of natural processes governing not only tree growth, but also carbon sequestration (Carton and Andersson 2017). The industry's expansion can therefore be interpreted, this paper argues, as an attempt to institute a "socioecological fix' to current forms of crisis" associated with the environmental and reputational risks of climate change in the EU's energy sector (McCarthy 2015, 2485; Ekers and Prudham, 2017).

One of the strengths of the 'real subsumption of nature' framework is its conceptualization of nature not as a set of external obstacles to be overcome by capitalist production (cf. FitzSimmons 1989; Kloppenburg 2004), but rather as a set of processes and systems that shapes the organization of production itself, through "ongoing relationship[s] and feedback effects" (Boyd, Prudham, and Schurmann 2001, 567)[1]. Few have dwelt for very long, however, on the origins of this thesis in Marx's ideas about the formal and real subsumption of *labor*. By contrast, this paper builds upon recent critiques of strictly humanist interpretations of Marx's work—and in particular their associated "straitjacket conceptualizations of labour, capital and value" (Barua 2019, 665; see also Hribal 2003; Barua 2017; Battistoni 2017; Krzywoszynska forthcoming)—by contending that plant metabolism (in the form of photosynthesis, growth and carbon sequestration) might usefully be conceptualized as a distinct form of nonhuman—in this case, vegetal—labor in its own right.

Typically of course, and as Marx (1976, 283) notes, "we presuppose labour in a form in which it is an exclusively human characteristic". Yet Marx himself did not insist on this view; instead, it is more accurate to say that he viewed labor as a "metabolic relation between nature and society: not a thing but a socionatural relation" (Robertson and Wainwright 2013, 895). For Smith (1984, 53), this metabolic relation is, at the most fundamental level, a process "by which the form of nature is altered"; moreover, in this process "[man] can *work only as nature does*, that is by changing the form of matter" (Marx 1976, 133, emphasis added). On the basis of their ability to metabolize alone then, plants cannot be discounted as potential sources of labor. And in the case of wood pellet manufacturing in the U.S. South specifically, this suggests that the ultimate success of any putative socioecological 'fix' being instituted by this industry must depend not strictly on "'improving' nature directly" (Boyd, Prudham, and Schurmann 2001, 565), but rather on optimizing the "heterogeneous entanglements" of human and vegetal labor which underpin both tree growth and carbon sequestration processes[2] (Barua, 2017, 283).

The concept of 'vegetal labor' has significant implications for scholarship addressing resource materialities and energy resource-making (Bakker and Bridge 2006; Kama 2019). At a theoretical level, it permits the replacement of coal with biomass in the EU's electricity sector to be viewed as a process whereby the 'living labor' of trees, growing in forests of the present day, replaces the “dead labor” (Kirsch and Mitchell 2004) of once-living organisms, as embodied in fossil fuels. Politically, meanwhile, recognizing and naming the “vital force” (Marx 1976, 341) of trees as labor promises to highlight the contingency not only of the production regimes animating working forests in the U.S. South, but also of the continual regenerative work which underpins the production of *all* forms of nonhuman biological life (Cooper and Waldby 2014). Indeed, the concept of ‘vegetal labor’ may open up new argumentative terrain from which to mount critiques of efforts to value nonhuman life as ‘natural capital’ (Helm 2015) or ‘ecosystem services’ (Kareiva et al. 2011), specifically by questioning the coupling together of value with notions of productivity, efficiency and indeed work in emerging forms of renewable ‘energopolitics’ (Daggett 2019).

The arguments presented in this paper draw upon data collected during multiple site visits to forest stands, wood pellet manufacturing facilities, and policy and corporate offices located in Louisiana, North Carolina and the UK, conducted during field visits in 2018 and 2019. Across these field visits, interviews were conducted with a total of 33 individuals involved in debates about the socioecological impacts of wood pellet manufacturing. These included eight representatives of the wood pellet industry (of which three were representatives of EU-based energy companies who consume wood pellets from the U.S. South region), seven representatives of other forest product industries, five professional foresters, nine environmental campaigners, and four independent forestry experts acting in an advisory capacity to policy-makers either in the U.S. or the EU[3]. Analysis of interviews and field notes focused on accounts of regional-scale forest dynamics and the history of industrial forestry activities in the U.S. South, the scale and nature of contemporary wood pellet manufacturing operations, and the forms of knowledge and practice required to optimize the management of working forest stands on the ground.

The remainder of the paper begins with a section outlining a more detailed case for conceptualizing bioenergy resource-making as a process underpinned by both human *and* vegetal labor. Section three then examines the specific interactions between human and vegetal labor through which the real subsumption of nature is achieved in working forests of the U.S. South, to the benefit not just of wood pellet manufacturing, but of the forest products sector more broadly. In section four, the paper turns its attention to the specific ways in which the wood pellet manufacturing industry harnesses vegetal labor, not simply as a means of accelerating forest productivity, but also as a means of claiming responsibility for apparent improvements to forests' overall contributions to climate change mitigation. It is on this basis, the paper argues, that wood pellet manufacturing should be understood as an attempted socioecological 'fix' for the crisis of climate change in the EU energy sector. In concluding, the paper advocates vegetal labor as a conceptual starting point for the development of alternative imaginaries of the kinds of work that forests and human societies might collectively enact, both in the U.S. South and elsewhere, in the face of climate change and other pressing socioecological challenges.

Animating Bioenergy Resource-Making: Plant Metabolism as 'Vegetal Labor'

The politics of biofuel—or for some, 'agrofuel'—production have occupied much critical social science scholarship[4]. Work in geography and science and technology studies, for example, has elucidated the discursive processes through which contemporary biofuel policies—particularly in the EU and U.S.—were originally formulated and rationalized (Gillon 2010; Palmer 2010), before subsequently being shored up amid numerous social and ecological concerns (Bailis and Baka 2011; Palmer 2014). Policy responses to these concerns, frequently turning on the establishment of sustainability criteria and supply chain safeguards, have since attracted their own academic critiques (Ponte 2014; Winickoff and Mondou 2017). For rural development scholars, meanwhile, a core concern has been to illuminate the impacts of biofuel production on “livelihood strategies associated with particular configurations of plants and people” (Bridge et al. 2013, 336), especially in the Global South (Vermeulen and Cotula 2012). Indeed, speculation about the profitability of biofuel production has been apprehended as a key contributor to widely-perceived accelerations in food insecurity, land enclosures and rural dispossessions—the latter often enacted on dubious legal grounds—since the turn of the century (Li 2010; Nally 2015).

Despite the breadth of these critiques, however, for Huber and McCarthy (2017, 655) many “miss what may prove to be the most significant aspect of the current global push for agrofuels: its potential to not only demand space, but to substantively remake it”. From this perspective, biofuel production comprises one among many elements of an ongoing “return to the surface for energy” (*ibid.*, 666)[5]—including wider investments in solar, wind, and hydropower infrastructures—that will precipitate dramatic landscape transformations across many parts of the globe, particularly in rural areas. These landscape transformations, moreover, are significant not just for their immediate social and environmental effects. Rather, they must be understood as visible manifestations of more fundamental, structural “reconfigurations of socio-natural relationships” (Ekers and Prudham 2015, 2441)—reconfigurations through which the global energy sector might, at least temporarily, stave off crises of accumulation and legitimacy associated with the environmental and reputational costs of fossil fuel burning.

In critical geography and political ecology, such reconfigurations are increasingly interpreted as a distinctly socioecological breed of spatial ‘fix’ (cf. Harvey 1981) for the innate crisis tendencies of capital. Defined as metabolic processes “during which society, nature and space are mutually transformed” (Bok 2019, 1099; see also Ekers and Prudham 2017), ‘socioecological fixes’ are not unique to the energy sector; urban green infrastructure projects (Nugent 2015) and reforestation initiatives (Ekers 2015), for example, have also been conceptualized in these terms. While there is no singular account of what a socioecological 'fix' *is* therefore (cf. Bakker 2009; Castree 2009)[6], where renewable energy specifically is concerned, these transformations have usually been theorized as manifesting in the form of large-scale investments in new kinds of fixed capital (such as wind turbines, solar farms, hydroelectric dams, or indeed bioenergy production facilities), as well as through the restructuring of relationships linking human labor power with raw materials (Ekers and Prudham 2015)[7]. A socioecological 'fix' in this context thus hinges, at least in theory, on "providing both opportunities for the reinvigoration of capital accumulation on a global scale *and* a biophysically significant response to climate change" (McCarthy 2015, 2495, emphasis added).

For Huber and McCarthy (2017, 656), the contemporary 'return to the surface' for energy will likely "not be biological as in preindustrial times, but based on the industrial and materially intensive production of solar and wind energy systems". Yet demand for bioenergy *is* forecast to grow precipitously over the coming decades (IRENA 2014), and is also increasingly being earmarked, through its putative large-scale combination with carbon capture and storage technology, as a future basis for achieving substantial *negative* greenhouse gas emissions (Beck and Mahony 2018). Moreover, unlike other renewable energy resources, bioenergy is unique in that living, metabolic processes are necessary not only to appropriate an existing (abiotic) energy resource and put it to work, but also more fundamentally to produce that (biotic) energy resource in the first place. Any study of relations of production in the bioenergy industry—indeed, of the processes through which this industry might successfully yield a socioecological fix for energy capital—must therefore attend not only to the structural relationships linking labor power, fixed capital and raw materials (cf. McCarthy 2015; Ekers and Prudham 2018), but also to practices of resource-making which are themselves inherently socioecological.

At one level, that bioenergy resources are constituted by living plants and trees may appear to reinforce longstanding distinctions, in resource geography and related literatures, between logics of extraction and logics of cultivation (see Boyd, Prudham, and Schurmann 2001). Yet this distinction—articulated starkly in Wrigley's (1988) juxtaposition of 'organic' and 'minerals-based' energy economies—breaks down if the temporal scope of the analysis is extended to account for historical processes of mineral resource formation. Albritton Jonsson's (2018, 84) assessment of nineteenth-century UK debates about prospective coal exhaustion, for instance, reveals nascent accounts of coal as "a providential gift, produced by a forested world now irrevocably lost to mankind". Such views naturally bear the hallmark of their time—most obviously, the need to reconcile geological theories of coal seam formation with theological commitments to creationism[8]. Yet the connection they establish between the photosynthesis of prehistoric plants and modern-day coal reserves is indisputable, and indeed finds echoes in more recent descriptions of such reserves as 'buried sunshine' (Mitchell 2009) or 'the subterranean forest' (Sieferle 2001). Recognized as the products ultimately of plant metabolism, coal reserves might even be regarded as a form of 'dead (vegetal) labor'—that is, as "work ossified and made concrete in the shape and form of a machine, a building, a finished commodity, a technological artifact, a piece of property, *or even nature itself*" (Kirsch and Mitchell 2004, 696, emphasis added).

By adopting a 'deep time' perspective on resource formation, the productive potential of plants—embodied in their capacity to metabolize solar energy, to grow, and indeed to sequester carbon—emerges as constitutive not only of Wrigley's (1988) preindustrial 'organic' energy economy, but also of the 'minerals-based' energy economy of the industrial revolution. Accordingly, this perspective invites us also to view *contemporary* bioenergy economies also as "constituted from the outset by a set of practices—including the 'performances' of non-humans" (Braun 2008, 669). Within social and cultural geography, plants have already been recognized as active contributors to practices of urban greening (Ernwein forthcoming), viticulture (Brice 2014), and even nation-building (Ginn 2008). Even as these ideas have emerged "through an empirics of humans and plants working together" (Head et al. 2014, 864; see also Fleming 2017) however, they have only rarely been extended to suggest that plants might be capable of performing labor *per se* (though for exceptions see Perkins 2007; Ernwein 2019). And, despite widespread conceptualizations of energy as 'the capacity to do work', the concept of vegetal labor has yet to animate analyses of contemporary economies of *bioenergy* resource-making specifically.

The idea of vegetal labor may be jarring if we presume the ability to preconceive the end goal of laboring—famously evoked by Marx's (1976, 284) juxtaposition of "the worst architect" with "the best of bees"—as sacrosanct (cf. Kallis and Swyngedouw 2018). Yet, for Perkins (2007, 1156), "nothing in Marx's writings precludes the idea that non-human organisms labor." And, as Huber (2017) and others have noted, Marx (1875) himself avers that labor "is only the manifestation of a force of nature"; theoretically therefore, any force of nature—human or nonhuman—might reasonably be apprehended as a kind of labor in its own right. Insisting upon this view—of labor as a "metabolic relation" (Robertson and Wainwright 2013, 895) in which "the form of nature is altered" (Smith 1984, 53)—is not intended to deny the existence of specifically-human forms of labor, whether "emotional" (Hochschild 2003), "immaterial" (Gill and Pratt 2008), or otherwise. Rather, the point is to affirm that the creation of capitalist value relies fundamentally upon "unpaid work done by living systems and other nonhuman natural processes" (McCarthy 2015), and moreover to suggest that by apprehending this unpaid work *as* labor—and not merely as an "ecological surplus" or "free gift" of nature (cf. Moore 2011)—we might open up new conceptual terrain from which to rethink the ultimate purpose of labor itself; indeed, to rethink the purposes of production and value generation more broadly (Daggett 2019; Krzywoszynska forthcoming).

In his examination of historical geographies of lion commodification and ecotourism in India, for example, Barua (2017, 283) suggests that production—normally taken for granted as the *telos* of labor—should be understood *not* as synonymous with making, but as "a process of setting up conditions of growth within which beings take on their particular forms or dispositions." Nonhumans can labor, under this reading, so long as we expand our definitions of labor to include those intransitive processes of growth which are exhibited nowhere more abundantly than in the plant kingdom, and whose temporalities and modalities emerge from relations both with other organisms (human and nonhuman), and with the wider environment within which that growth occurs. Moreover, if understood as growth rather than as making, labor might be reappraised not just as a shared capacity of human *and* nonhuman organisms, but also as an open-ended process whose contribution to higher ends need not be tightly prescribed by capitalist logics of efficiency, productivity, or indeed value itself.

Fundamentally concerned as it is with 'setting up conditions of growth' (Barua 2017), wood pellet manufacturing—one element of a broader contemporary reinvention of plant-based energy systems—thus seems almost intuitively well-suited to analysis through the lens of vegetal labor. Yet this lens also has potentially significant implications for existing theories of the socioecological 'fix', opening up the possibility that capitalist crises might be averted not only by restructuring relationships between human labour and raw materials—as in the process of fixed capital formation (Ekers and Prudham 2018)—but also by enrolling previously underexploited, *nonhuman* labor power, as part of alternative resource-making practices. Building on these ideas, the following two sections of the paper now engage in a detailed analysis of the wood pellet manufacturing industry, focusing on the processes and pathways through which vegetal labor is enrolled not only in the production of tangible bioenergy resources (whereby wood pellets function as a combustible fuel), but also in the production of legitimacy to undergird claims about that industry's climate change mitigation benefits (whereby wood pellets function as a material embodiment of enhanced carbon dioxide sequestration in the forests from which they were derived).

Subsuming nature in the working forest: From 'taming trees' to hybrid labor

Stretching from Texas and Oklahoma through to Virginia and the Carolinas, the forests of the U.S. South cover approximately 250 million acres, comprising largely privately-owned, often intensively-managed stands of loblolly pine and assorted hardwood species including oak, hickory, sweetgum, maple and cypress (Oswalt et al. 2019). With the majority of the region's old-growth forests initially having been cleared at least a century ago[9], much of the present-day tree cover is referred to explicitly as 'working forest', denoting its use for the production of diverse wood-based commodities. And, having long been responsible for a disproportionate share of global paper, pulp and saw-timber production (Oswalt and Smith 2014), these forests are now playing host to a rapid expansion in wood pellet manufacturing, as bioenergy interests seek to capitalize on the region's abundant wood resources, well-established forestry infrastructure, and deeply-embedded silvicultural expertise.

The intensity of the transformations at hand in the southern U.S. today is evidenced by satellite data showing that forest disturbance rates were approximately four times greater, between 2000 and 2012, than those prevailing in South American rainforests, with 31% of forest being lost or regrown in this period (Hansen et al. 2013). Such prodigious disturbance can be partially attributed to the long-term success of "industrial tree improvement programs" (Prudham 2003), which, since the 1950s, have gradually developed more vigorous genotypes of commercially-important species. With respect to loblolly pine, near-ubiquitous in working forests in the region, such programs have increased final-harvest tree volumes by an estimated 20–35% compared to "unimproved seedlings" (McKeand et al. 2006, 179). Consequently, typical rotation periods—the length of time required to produce loblolly pines large enough to supply high-quality timber to the saw-log industry—have been reduced to around twenty-five to thirty years (Prudham 2005, 62).

In refusing to confront trees "as 'ready-made' objects" (Boyd, Prudham, and Schurmann 2001, 566), industrial tree improvement programs constitute a classic example of the real subsumption of nature. Yet there are additional ways in which capital has engaged in "ongoing intervention in and alteration of tree growth processes" (*ibid*., 566) in working forests of the U.S. South, on the basis of which it may be possible to develop a more nuanced understanding of nature's 'real subsumption'. Crucially, these additional techniques operate not at the genetic level (targeting individual tree characteristics), but at the landscape level (targeting interactions *between* the various trees in a stand). As the U.S. South region furnishes the EU's electricity sector with increasing quantities of wood pellets, these landscape-level practices have come to play a crucial new role in underpinning claims about the purported climate change mitigation benefits of deriving bioenergy from forests.

Paramount in this regard is the longstanding practice of 'thinning', where a moderate proportion of trees is removed from a stand to preempt competition; for loblolly pine this is typically once trees reach an age of 10–12 years (Cunningham, Barry, and Walkingstick 2008). The ultimate aim, as one wood pellet industry representative puts it, is "reducing density so you can get some volume on the other trees" (Interview, May 2019). While precise thinning techniques respond to individual stand characteristics and market considerations, such operations usually hinge on removing every third, fourth or fifth row of planted trees, as well any other planted trees deemed weak or poorly-formed in comparison to their neighbours. As one interviewee explained, "you lose some good trees, but you also get rid of all the weaker ones" (Interview, Wood Pellet Industry Representative, April 2018). Crucially, thinning not only enables income to be derived from stands of planted loblolly pines well before trees have reached full saw-log size; in freeing up light and space for those trees that do remain, it also permits "growth to be put on the *better* trees in the stand" (Baker and Langdon 1990, 503, emphasis added). Absent thinning, by contrast, trees would eventually begin to compete directly for space and light, resulting in slower average growth rates across the stand, and more prevalent deformities in shape[10].

Across the U.S. South, 'thinnings'—also referred to as pulpwood or small-diameter roundwood—have historically been the mainstay of the paper and pulpwood industries. Although this sector is currently undergoing significant restructuring[11], interviewees were at pains to emphasize that, to date at least, wood pellet manufacturers' overall use of thinnings "has not even come close to replacing paper" (Interview, Forest Product Industry Representative, May 2019). Nevertheless, wood pellet manufacturing in the region *is* increasing significantly; to the more than twenty pellet mills whose estimated output exceeded 10 million tons in 2019 (Oswalt et al. 2019, 47), the Southern Environmental Law Centre (2019) estimates that another seven, capable of producing a further 4.8 million tons per year, will soon be added. *Enviva*, the region's most prolific wood pellet manufacturer, will build the two largest of these new plants, in Alabama and Mississippi, each with an annual production capacity in excess of 1 million tons. According to recent filings with the U.S. Securities and Exchange Commission (2019), the company expects to double its total production of wood pellets in the U.S. South region by 2025, with contracts in place to export not only to EU countries, but also to Japan and South Korea.

While thinning is by no means a new practice therefore, its continued prevalence across the working forests of the U.S. South is vital in satisfying rising demand, in the EU and elsewhere, for wood pellets. This is not to say that wood pellet manufacturing relies exclusively on thinnings; indeed, accusations abound that much wood supplied to pellet mills in the U.S. South arises not from the thinning of planted forests at all, but from unmanaged stands growing in ecologically-sensitive landscapes, such as the bottomland hardwood forests of the region's coastal plains (Fanous and Moomaw 2018). Nonetheless, thinning is central to maximizing the extraction from working forest stands in the U.S. South of *multiple* kinds of values, embodied not only in those trees which are removed (and which go on to become wood pellets themselves), but also in those which are left in place to continue growing more vigorously than they otherwise would have done. And, as the next section will outline, it is on this basis that wood pellet manufacturers ultimately advance claims about the climate mitigation benefits of working forests, thereby effectively positioning forest-based bioenergy as a form of socioecological 'fix' for the EU energy sector. Before moving on to scrutinize these claims however, it is necessary first to examine in greater detail the forms of labor—both human and vegetal—that constitute the practice of thinning.

As noted in the previous section, plant growth *has* been recognized as a form of labor by human geographers in the past (Perkins 2007; Ernwein 2019), though usually in urban rather than rural settings. Perkins (2007, 1156), for example, has argued that elm trees planted in "unprecedented numbers and density throughout the growing industrial cities of the American Northeast and Midwest", especially during the late-nineteenth and early-twentieth century, effectively performed what he terms 'nonsocial' labor by producing use-values for human social reproduction. As their "long arching limbs enveloped neighborhood streets in green cathedrals", Perkins writes, elms labored by providing "relief from the heavily industrialized settings in which much of the working class toiled" (*ibid.*, 1156). In this analysis, trees "do not wield as much power… as the people who choose to plant, maintain and remove them" (*ibid.*, 1157). Yet, even as the very presence of elms in cities depends upon human ideas and actions, Perkins (*ibid.*, 1157) suggests that elms themselves perform the "'work' of growing in part by enrolling or appropriating/exploiting the labors of… social actants [i.e. workers trained to maintain urban elm 'forests'] thereby producing networks conducive to their own benefit".

In working forests of the U.S. South, vegetal labor contributes not to human social reproduction, but production itself. Yet it remains possible to discern a similar multidirectional process of enrolment enjoining trees and humans in these forests. Since the goal of thinning is to minimize competition between trees, it demands first-and-foremost a close attunement to the ways in which trees impact on their neighbours by exhibiting complex, non-uniform forms and temporalities of growth (and not simply a concern with making trees grow more quickly on their own terms). Hence considerable emphasis is placed on hiring forestry professionals who can "get a very good feel for the ideal 'target stocking density'" of any given stand of loblolly pine trees (Interview, Wood Pellet Industry Representative, April 2018). The ability of foresters to foresee how their decisions—about which trees to remove and which to leave standing—will carry forwards in the form of altered interactions between trees left in place over the coming years, or even decades, is crucial here. Yet this ability is underpinned by embodied, "affective ways of knowing nature" (Peltola and Tuomisaari 2015, 1) as much as it is by strictly codified rules; consequently, the effective thinning of working forest stands relies upon human labor whose modalities are always inextricably influenced by the *vegetal* labor of trees themselves.

Another critical component of thinning is judging whether the time is right to thin at all; or, as one wood pellet industry representative puts it, pinpointing when it is "silviculturally sensible to intervene" (Interview, April 2018). In seeking to identify the moment at which tree growth in an un-thinned stand will begin to be suppressed by competition, foresters monitor trees' average diameter, their total basal area (or footprint, measured per acre), and perhaps most importantly, their 'live crown ratio' (the distance between the top of the tree and the lowest branch playing host to live leaves). Commit to thinning too soon, and not only will the quantity and quality of roundwood yielded from the operation be suboptimal; remaining trees will also be more likely to "broaden out" at the expense of becoming as tall as possible (Interview, Wood Pellet Industry Representative, September 2018). Postpone thinning for too long, however, and trees will already have had their growth suppressed; subsequently, even with newly-acquired light and space to exploit, branches in the live crown playing host to needle leaves vital for photosynthesis, and hence growth, will be of suboptimal size, and indeed "stand growth rates will never recover" (Interview, Professional Forester, May 2019). One wood pellet industry representative even goes as far as to compare the live crown of loblolly pine trees to an engine, arguing that when thinning is carried out too late, remaining trees "won't have a big enough engine to have the best possibility to achieve full log size" (Interview, April 2018).

Thinning, this paper argues, is thus the core practice through which forest-product industries seek to overcome obstacles presented by the indeterminate (albeit constrained) temporalities and modalities of vegetal labor as it is performed by trees in working forests (whether those indeterminacies and constraints arise from the trees' genetic characteristics, or from the complex, stand-level ecological interactions within which trees 'labor' in practice) (Prudham 2005, 12–15). Since the success of thinning depends upon optimizing interactions both among trees, and between trees and humans, however, it follows that the extraction of surplus value from working forests of the U.S. South by these industries relies not exclusively on human labor, but rather on a more-than-human arrangement of what Battistoni (2017) has termed "hybrid labor", in this case comprising human *and* vegetal components.

Following Smith (2007), the real subsumption of nature in industrial forestry can therefore be said to depend not only on making nature work "harder, faster, and better" (Boyd, Prudham, and Schurmann 2001, 564)—that is, on 'taming trees' through industrial improvement programs (Prudham 2003)—but also on instantiating an explicitly *cooperative* register of 'hybrid labor' among trees, and between trees and humans. As the next section will now show, while wood pellet manufacturing specifically is not unique in its reliance upon this hybrid labor regime, the regime's dynamics *are* central to that industry's ability not only to extract surplus value from working forests of the U.S. South in the form of energy, but also to legitimize wood pellet manufacturing itself as a climate change mitigation tool, and thus to position it as a socioecological 'fix' for ongoing forms of crisis associated with climate change in the energy sector.

Bioenergy resource-making as a socioecological 'fix': Vegetal labor and the forest carbon conveyor

As wood pellet manufacturing in the U.S. South expands, working forests are increasingly viewed not only as the means of production for diverse wood-based commodities, but also as renewable 'biorefineries' producing biological alternatives to fossil fuel (Zhu 2011). To date, however, much of the commercial appeal of wood pellet manufacturing has derived not strictly from the presence of demand for renewable fuels in the EU, but rather from the regulatory classification of biomass fuels in this context as inherently carbon neutral. Within the EU's (2018) Renewable Energy Directive, carbon dioxide emissions released upon the combustion of biomass fuels are in fact counted as zero, on the assumption that those emissions will already have been accounted for within the land-use sector of the country where biomass was originally cultivated (Searchinger et al. 2018)[12]. In the UK specifically, it is on the basis of this assumption that government commitments to subsidize the conversion of numerous coal-fired electricity generation facilities to run on biomass fuels have ultimately been rationalized. *Drax Group plc.*, for example, the UK's largest consumer of wood pellets, received an estimated £789.2 million of government funding in 2018, in exchange for burning approximately 7.2 million tonnes of wood pellets, over 60% of which were imported from the U.S. (Drax Group plc. 2019)[13].

That wood pellets are officially classified as carbon neutral in EU law has not prevented them from courting controversy. Concerns have been raised not only about the alleged sourcing of wood from unmanaged forests in ecologically-sensitive areas (as noted in the previous section), but also about emissions of carbon dioxide and other pollutants generated in processing wood pellets in the U.S. (Koester and Davis 2018), not to mention transporting them to the EU. Disquiet is also attached to the potentially long time periods required for tree growth to recoup the carbon emissions which are—incontestably—released when pellets are combusted to generate electricity (Schlesinger 2018). Aware of the contentiousness of official carbon accounting methodologies, key actors in the wood pellet sector have thus sought to develop their own arguments about the material basis of the industry's purported climate mitigation benefits. At one level, these arguments can be read as an effort to downplay the risks associated with investing in the expanding wood pellet manufacturing economy, thereby enhancing the "resourceness" (Kama 2019) of forest-based bioenergy itself. Yet the goal here is not strictly to demonstrate the feasibility of extracting energy from forests on a long-term basis (as with efforts to 'materialize' speculative unconventional hydrocarbon reserves, for example), so much as it is to secure "the legitimacy of particular social orderings and the consolidation of particular socioecological relations" (Ekers and Prudham 2018, 29) associated with wood pellet manufacturing. These arguments should be viewed as a central part, in other words, of efforts to institute wood pellet manufacturing in the U.S. South not just as a legitimate source of renewable energy, but also more ambitiously as an effective socioecological 'fix' for ongoing forms of crisis linked to climate change in the EU energy sector.

At the heart of these arguments is a specific view of the 'working forest' itself. Previously an unassuming label for any forest stand managed deliberately for commodity production, in the hands of the wood pellet sector the idea of the 'working forest' has been carefully recast as a silvicultural paradigm capable not merely of sustaining the intensive production of diverse wood-based commodities, but also of actively *enhancing* the forest's ability to sequester carbon dioxide. As the UK's largest consumer of wood pellets explains on its website:

> "The technique is to harvest trees when they have stopped growing at a fast rate, use the wood for forest products such as timber, pulpwood or compressed wood pellets for energy and replant the area with new, high growth potential trees. The result is a forest with *a steady stream of CO_2-hungry young trees and a steady stream of renewable raw material*." (Drax Group plc. 2016, emphasis added)

In privileging overall rates of photosynthesis, tree growth, and carbon sequestration, this view of the working forest aims to reconcile the objective of using forests for commodity production on the one hand, and the objective of using forests to sequester carbon dioxide on the other. From this perspective, the real climate change mitigation potential of any given stand of forest lies not strictly in its capacity to *store* carbon dioxide. Rather, what counts is the ability of a "steady stream of CO_2-hungry young trees" to continually draw carbon dioxide down from the atmosphere at the highest possible rate. This is a view, ultimately, of the working forest not as a carbon sink, but as a carbon *conveyor*—one whose contribution to climate change mitigation is determined by the rate at which it generates raw materials for use in the production of a wide range of commodities, including not only wood pellets, but also books, packaging, furniture and construction materials.

Such a view of the working forest is significant firstly because it establishes a hierarchy of preferences for trees based upon their relative productivity—in effect, actively discriminating among trees according to the amount of vegetal labor they perform over a given period of time. The total quantity of CO_2 stored by a given tree over the course of its life is here superseded, as a parameter to be maximized, by its rate of CO_2 *absorption* in the present. Younger loblolly pines are thus preferred because they grow more vigorously than their older counterparts, achieving greater proportional volume increases, and also sequestering more carbon relative to their size, over any given time period.[14] As *Drax Group plc.* (2017) contends on its own website, “older trees will have more carbon stored (after a ‘childhood’ spent absorbing it), but if these are not harvested… their carbon absorption plateaus”. While the distinction between carbon dioxide storage and carbon dioxide absorption may appear subtle, a focus on maximizing the latter over the former has vastly different implications for forest management. Put simply, from this standpoint, a stand of juvenile trees appears far more advantageous to climate change mitigation than a stand of larger, more mature but nonetheless slower-growing trees. Dynamism and productivity are hence privileged over size and stability, and a clear moral economy of vegetal labor is established in which younger, ‘harder-working’, and more vigorous trees are regarded as more virtuous than older, ‘lazier’, and relatively moribund ones (cf. Paxson 2017; Daggett 2019).

Just as significant as this underpinning moral economy of vegetal labor, however, is an insistence that wood pellet manufacturing’s contributions to climate change mitigation cannot be disentangled from those of the wider ecosystem of forest product industries whose presence in the U.S. South region *collectively* serves, in the words of one wood pellet industry representative, “to hold things in this pine position” (Interview, April 2018). The purported reliance of wood pellet manufacturing upon small-diameter roundwood harvested during thinning operations is crucial here, since it enables protagonists of the industry to position their activities as subordinate to those of industries reliant upon larger and more valuable saw-logs. As one interviewee explained during a site visit to a wood pellet mill, “anything larger than 18 inches in diameter has no business being here; it was growing to be something other than a pellet” (Wood Pellet Industry Representative, May 2019). The insistence of one forest product industry representative, meanwhile—that “nothing that we plant is just for wood pellets" (Interview, May 2019)—was widely confirmed by other interviewees, including forestry experts and environmental campaigners. Even as the wood pellet sector expands, therefore, at the level of the U.S. South region as a whole, landowner planting decisions continue to be driven principally by high prices for full-sized saw-timber.[15]

While thinned wood may be economically subordinate to high-value saw-timber, however, the practice of thinning itself, as discussed in the previous section, nonetheless underpins efforts to maximize the extraction of multiple use values from the working forest, including those embodied in trees both removed *and* left in place to continue growing. Even as it constitutes a "side-stream from high-value timber production" therefore, from this perspective the wood pellet sector's incentivization of thinning enables it to "really contribute beyond its direct footprint… bringing benefits throughout the forestry sector" (Wood Pellet Industry Representative, September 2019). Were wood pellet manufacturing to cease, the argument goes, this would act not merely to reduce the available quantity of biomass fuel with which to replace coal in European power stations—it would compromise the ability of working forests in the U.S. South to convey carbon dioxide out of the atmosphere and into *other* commodity forms as well. The production of wood pellets makes sense, in other words, not just because of their ability to replace coal, but also because their production calls into being, and indeed reinforces over time, a particular kind of hybrid labor regime in the working forest. What counts is the capacity of this hybrid labor regime—based around dense planting, vigorous initial tree growth, and astute, well-timed thinning—to enhance the average carbon sequestration *efficiency* of the working forest, even if that regime may not materially enhance the overall quantity of carbon physically *stored* by the forest over time.[16]

In contending that the optimal working forest is one in which overall rates of photosynthesis, tree growth and carbon sequestration are maximized, protagonists of wood pellet manufacturing aim to supplant a view of forests contributing to climate change mitigation by operating as gradually accumulating carbon *sinks*, with a view of forests as contributing to the same goal by operating as dynamic, high-throughput carbon *conveyors*. The aim of this discursive move, this section argues, is to legitimize the consolidation of a highly-specific set of socioecological relations within forests of the U.S. South (cf. Ekers and Prudham 2018), ultimately by attributing the climate change mitigation benefits of those relations directly to their orientation towards accelerating the production of a range of commodities (including not only wood pellets, but also paper, roof beams and writing desks). Indeed, for one forest product industry representative, the case for wood pellets being good for climate change mitigation would simply "fall apart if wood was being grown specifically for biomass" (Interview, May 2019).

While the concept of a socioecological 'fix' is not invoked explicitly by wood pellet manufacturers (or indeed other supporters of the wood pellet sector), this section nevertheless contends that efforts to normalize a view of working forests as carbon *conveyors* should be understood as vital to the work of instituting such a fix in practice. Yet this is a socioecological fix which differs substantially from that discerned in assessments of renewable energy as a vehicle for renewed accumulation driven by large-scale investments in new forms of fixed capital, such as wind turbines, solar farms, or tidal lagoons (McCarthy 2015). Instead, the socioecological fix of wood pellet manufacturing aims principally to respond to a crisis of *legitimacy* associated with coal-fired electricity generation in the EU, and is based ultimately on the appropriation of vegetal labor from already-intensively managed working forests. Under the terms of this 'fix', moreover, forests not only come to be seen (for the first time since the advent of plantation forestry) explicitly as energy resources; they also become the latest example of an industrial fuel system intimately coupled, in Daggett's (2019, 5) terms, "to the gospel of labor and its veneration of productivity". For those seeking to articulate compelling alternatives to the rapid expansion of wood pellet manufacturing in the U.S. South, therefore, there is a need not only to interrogate the sector's climate change impacts on their own terms, but also more fundamentally to question the presumption that climate change can best be tackled by putting more, and not less, of the world's forests to productive work.

Conclusion: Working (with) forests for what?

This paper has argued that the expansion of wood pellet manufacturing in working forests of the U.S. South should be understood as an attempted socioecological 'fix' for the environmental and reputational costs of coal-fired electricity generation, both in the EU electricity sector and increasingly elsewhere. However, whereas existing accounts of renewable energy as a socioecological fix for capitalist crisis linked to climate change have tended to emphasize the role of large-scale investments in new forms of fixed capital (McCarthy 2015; Ekers and Prudham 2018), the socioecological fix described in this paper hinges critically on harnessing the labor power of nonhuman—in this case vegetal—lifeforms. Indeed, in so far as it can claim to decouple large-scale electricity generation from climate change, wood pellet manufacturing does so—this paper argues—ultimately by replacing the "dead labor" of prehistoric plants (cf. Kirsch and Mitchell 2004), as embodied in fossil fuels, with the living, 'vegetal labor' of present-day trees, as embodied in biomass fuels.

Yet, in the EU context at least, the efficacy of this fix cannot be irrefutably demonstrated by official carbon accounting methodologies, which contentiously assume that *all* biomass fuels produce zero carbon dioxide upon combustion (Searchinger et al. 2018). Consequently, against claims that the climate benefits of forest-based bioenergy can be modest, or potentially even non-existent (Matthews et al. 2015; Schlesinger 2018), protagonists of wood pellet manufacturing in the working forests of the U.S. South do not seek to isolate the climate change mitigation contributions of this industry as a discrete entity.

Instead, they emphasize its interconnectedness with other forest product industries also reliant—whether directly or indirectly—upon the silvicultural practice of thinning, thereby insisting on the need to examine rates of photosynthesis, tree growth and carbon sequestration achieved by the working forest *as a whole*. From this perspective, forest-based bioenergy achieves a socioecological fix by enhancing the rate at which working forests convey carbon dioxide out of the atmosphere and into not only biomass wood pellets, but a diverse array of other commodity forms as well.

While normally considered as a craft skill enacted by trained forestry professionals, this paper has argued that thinning should be understood as a distinct vehicle for the 'real subsumption of nature' (Boyd, Prudham, and Schurmann 2001), predicated ultimately upon the optimization of interactions between human *and* vegetal labor in working forests. Moreover, in the hands of the wood pellet manufacturing industry specifically, this practice acquires importance not strictly for its ability to ensure the production of high-quality roundwood and saw-logs, but rather for its ability to enhance working forests' contributions to climate change mitigation. Conventional views of forests as gradually accumulating carbon sinks are here supplanted with an alternative ideal, in which forests contribute most effectively to climate mitigation by operating as what this paper has termed high-throughput carbon *conveyors*. This ideal, moreover, entails the establishment of a moral economy of vegetal life in which younger, 'harder-working', and more vigorous trees are regarded as more virtuous and beneficial—from a climate change perspective—than older, 'lazier', and relatively moribund ones (cf. Daggett 2019).

Recognizing and naming the 'vital force' of plants and trees (to photosynthesize, grow, and sequester carbon) as vegetal *labor* may at first seem counterintuitive, at least in that it appears to privilege a view of forests as reserves of untapped economic value waiting to be 'put to work'. Even as it may seem absurd to describe loblolly pine trees in the U.S.

South as laborers, however, the point of this move is not to reduce trees to the status of docile workers, or indeed to imply that trees—like humans—can preconceive the end goals of their labor. Instead, the point is to reclaim the concept of labor itself, as first and foremost a metabolic, relational capacity, shared by human and nonhuman lifeforms alike, to change the form of matter, and moreover to do so in a multitude of ways (cf. Smith 1984; Barua 2017).

Understood in these terms, vegetal labor offers a conceptual means of transcending polarizing debates about capitalism and nature, in which calls to protect the "intrinsic value" of a supposedly pristine, external nature are cancelled out by discourses of 'natural capital' (Helm 2015) and 'ecosystem services' (Kareiva et al. 2011). Recognizing and naming the vital force of vegetal life as labor, while also insisting that that labor is inevitably political (cf. Battistoni 2017), reveals the flaws of both approaches. The ecological can never be fully occluded from economic logics, just as the economic can never fully exhaust the possibilities of the ecological. Neither climate change, nor indeed any other environmental crisis, will be remedied through commitments to reappraise the capacities of trees—whether to grow, to sequester carbon, or otherwise—as 'natural capital', or indeed as 'ecosystem services' (Ojha et al. 2019). It is precisely the flaw of all efforts to prescribe tidy, definitive economic correctives for the environmental 'externalities' of industrial capitalist activity that their ability to 'protect' nonhuman nature depends upon *naturalizing* the very logics of efficiency and productivity upon which capitalist social relations are based (Krzywoszynska forthcoming).

What the concept of vegetal labor invites, by contrast, is an effort to imagine—and potentially to begin to assemble—explicitly socionatural working collectives wherein the purpose of collaboration (literally 'co-laboring') would be untethered from the "necessity and mundane considerations" prescribed by capital (Marx 1976, 820), and oriented instead towards higher, self-determined end goals. Where wood pellet manufacturing specifically is concerned, the concept thus emboldens us to complement critiques of forest degradation, and in some cases alleged deforestation, with alternative forms of open-ended experimentation in working *otherwise* with forests, and, in the process perhaps, to invent "new cultural values beyond profit and efficiency" (Huber 2018, 156). In short, it challenges us to question the core assumption situated at the very heart of the apparent socioecological 'fix' constituted by bioenergy resource-making—the idea that climate change as a socioecological crisis can best be tackled by putting *more* of the nonhuman world to productive work, and not less.

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[1] This approach presages ‘new materialist’ scholarship, wherein resource governance is seen to be actively shaped by the “generative capacities of biophysical processes” (Bakker and Bridge 2006, 19; Richardson and Weszkalnys 2014).

[2] This perspective chimes with Bakker and Bridge’s (2006, 19) view of the ‘production of nature’ as “a ‘coproduction of socionature’ in which humans and nonhumans alike participate (albeit unevenly, and subject to dynamic and evolving constraints)”.

[3] For ethical reasons, interviewees’ names and organisational affiliations are not disclosed.

[4] The term ‘agrofuel’ is preferred by some to ‘biofuel’, since the former better connotes “competition for scarce crop-land, deforestation and so on” (McMichael 2009, 283).

[5] In abstract terms, this move entails abandoning subterranean *stocks* of fossil energy (assembled very slowly, over geological timescales), and harnessing instead above-ground *flows* of solar energy (manifesting on much shorter timescales).

[6] Thanks to an anonymous reviewer for pointing this out.

[7] One notable exception is Behrsin’s (2019) careful analysis of the discursive and material pathways through which the EU’s ‘waste-to-energy’ industry has effectively been “rendered renewable”.

[8] Albritton Jonsson (2018, 89) quotes William Buckland’s 1836 *Bridgewater Treatise on The Natural History of the Earth*, wherein the famed geologist and cleric argues that in burning coal: “We are all brought into immediate connection with the vegetation that clothed the ancient earth before one half of its actual surface had yet been formed.”

[9] As Prudham (2005, 96) notes, a "wave of essentially extractive forestry" sequentially liquidated the majority of old-growth forest stands in the U.S. Northeast, the Great Lakes, and the Southeast in the period between the early 1800s and 1920—and was by the 1940s well on its way to doing the same in the Pacific Northwest (see also Williams 1989).

[10] Since they reduce stand density and provide opportunities to eradicate unhealthy trees, thinning operations are also sometimes credited with reducing the forest's susceptibility to wildfire and to insect-borne disease (Cunningham, Barry, and Walkingstick 2008).

[11] The paper and pulp sector is declining in some localities and consolidating elsewhere, as demand for conventional paper is increasingly superseded by demand for other commodities including cardboard packaging and hygiene products.

[12] Annex VI of the EU's (2018) Renewable Energy Directive declares that "emissions of CO_2 from fuel in use… shall be taken to be zero for biomass fuels".

[13] Two distinct payments are issued, one under the UK Government's Renewables Obligation, and the other under so-called 'Contracts for Difference', which guarantee a specific price for any electricity generated by former coal-firing power units converted to run on biomass fuels (Drax Group plc. 2019).

[14] It is important to emphasize that these are *relative* measures. Moomaw, Masino, and Faison (2019) contend that older trees sequester greater *absolute* volumes of carbon dioxide than younger, ostensibly more vigorous trees each year, simply because of their size.

[15] This is not to say that the construction of wood pellet mills does not have impacts on landowner planting decisions at a local scale (since a significant proportion of the cost of any thinning or harvesting operation arises from the onward transportation of wood).

[16] Lewis et al. (2019), for example, estimate that naturally-regenerating forests are around 40 times more effective than planted forests at maximizing total carbon storage (in both forest vegetation and soils).